Performance of Nonwoven Geotextile in Coastal Protection Works with Marine Clays

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ABSTRACT: This paper evaluates the long term performance of nonwoven-needle punched geotextile filter used on marine clays, which prevail along the coastlines in Asia. The long term performance of the geotextile was investigated by exhuming the geotextiles from two coastal projects in Malaysia after more than five years performance. The filtration and mechanical properties of the exhumed geotextiles were tested to establish appropriate long term geotextile filter design criteria for cohesive soils and the required mechanical properties for construction survivability. These filter design criteria together with geotextile properties critical for construction survivability are presented and recommended for typical Asian coastal revetment construction conditions.

1 INTRODUCTION

Erosion of coastlines and riverbanks is a major problem throughout South East Asia. Large areas of coastlines, riverbanks and deltas comprise highly erodable fine silty soils that warrant effective erosion protection to arrest the problem. Nonwoven needle-punched geotextiles are commonly used as filters in revetment protection works. This requires the geotextiles to be placed in contact with, and filter such soils under turbulent reversing flow conditions without significantly impairing their long term filtration capabilities. However, the criteria used to design geotextile filters were developed in Europe or the USA and limited or no investigations have been carried out to confirm the applicability of the criteria for Asian soil and engineering conditions.

To better understand the long term performance of continuous filament nonwoven needle-punched geotextile filters in contact with fine silty soils, it was decided to exhume geotextiles from two sites that typically represent Asian regional conditions. These sites, A and B, are located at the western coast of Peninsular Malaysia (Figure 1) where the geotextiles have been installed more than five years over deep deposits of marine clays that prevail within the region. Details of the sites, excavation and results of the study are presented in subsequent sections.

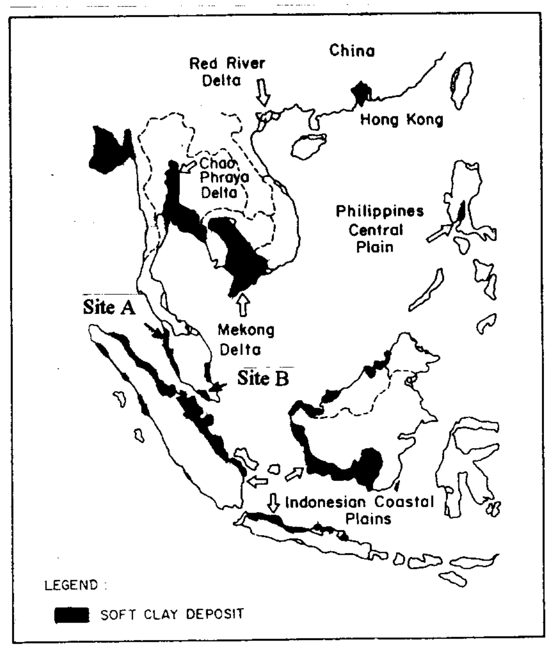


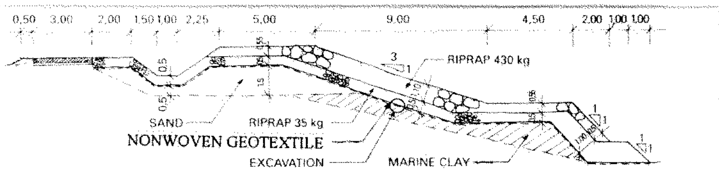
Figure 1. Distribution of soft clay deposit in South East Asia and locations of excavated site.

2 SITE LOCATIONS

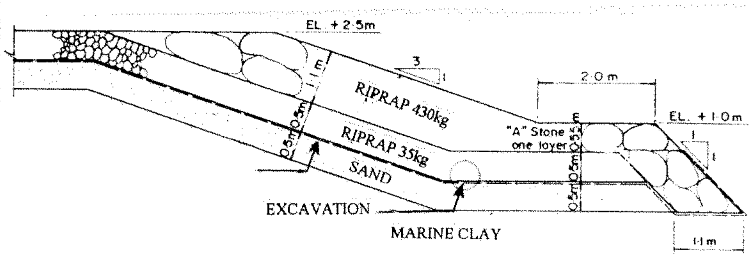
2.1 Site A - Pantai Murni, Kedah

The site of this excavation is a coastal revetment structure located near the Pantai Murni river mouth. The revetment structure, constructed in 1986, comprised a continuous filament nonwoven needle-punched geotextile filter overlain by 0.5m thick secondary rock armour of mean weight 35kg and primary armour consisting of 1.1m rock armour with a mean weight 430kg laid at gradient 3H:1V.

Excavation was carried out at two locations, X and Y, about 80m apart. At location X, the geotextile was laid directly over deep deposits of marine clay. At location Y, the geotextile was underlain by a layer of sand 0.5m thick above the marine clay. The cross-sections of the revetments are shown in Figure 2.



Location X



Location Y

Figure 2. Cross sections of revetments at site A.

2.2 Site B - Pontian, Johore

This coastal bund was constructed in 1986 to protect the shore from erosion due to severe tidal wave action. The bund consisted a continuous filament nonwoven needle-punched geotextile filter, laid directly over marine clay, and overlain by two layers armour rock comprising of 1m thick primary armour (100-300kg) and 0.6m thick secondary armour (5-20kg). The slope of the protection bund was maintained at a typical gradient of 3H:1V. Figure 3 shows the cross section of the coastal bund.

3 EXCAVATION AND OBSERVATIONS

Excavations of both sites were executed in October 1992 under the supervision of representatives from the geotextile manufacturer and the Drainage and Irrigation Department. The revetments before excavation at both sites were in excellent conditions (Plate 1). Excavation was carried out during low tide using a long arm showel excavator. Secondary armour stones directly above the geotextile were removed by hand to avoid mechanical damage to the geotextile. During excavation, it was observed that the geotextile conformed well to the

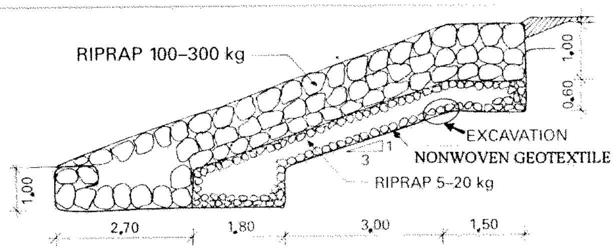


Figure 3. Cross section of coastal bund at site B.

subsoil/rock armour profile and no installation damage was visible from the excavated geotextile samples. After excavation, a new geotextile was placed, with overlap of approximately 1m, over the perimeter of the existing geotextile. Armour rocks were then placed to the original gradient of the revetments.

Plate 1. Condition of the revetment before excavation - Site A.

4 TESTING OF EXCAVATED GEOTEXTILES AND SOIL SAMPLES

The long term performance of the excavated geotextiles were evaluated based on their hydraulic and mechanical properties. The hydraulic properties were investigated in Delft Hydraulics, Holland and the Franzius Institute, Hanover, where index tests on the pore opening size and vertical water flow of the geotextiles were conducted. Evaluation on the mechanical properties of the excavated geotextiles were also undertaken.

4.1 Hydraulic properties

The tests for the opening pore size and permeability of geotextiles were conducted using the wet sieving method in accordance to DIN 53935 and NEN 5167 respectively. Tests were carried out on the excavated samples in dirty and cleaned conditions. Tests were also conducted on original geotextile samples supplied by the manufacturer for comparisons.

Table 1 shows the results of the pore opening size

$O_{90,w}$ and permeability, k_n of the geotextile samples. The values given are average values obtained from testing five samples of each geotextile type.

4.2 Mechanical properties

Tests carried out to determine the residual strength of the geotextiles were strip tensile (DIN 53857), CBR puncture (DIN 54307) and grab (ASTM D4632). These tests were chosen to allow the types of stresses exerted on the geotextiles in a typical coastal revetment system to be accurately assessed. Table 2 shows the comparisons between the excavated and original samples of the geotextile mechanical and physical properties.

4.3 Subsoil properties

The particle size distributions of the soils excavated from both sites A and B, are given in Figure 3. Further information on the contents of subsoil near the excavated sites, were also obtained from the local authorities and Ting et al, 1987. These showed a distribution of about 40-50% clay; 35-60% silt and 5-10 % sand near the soil surface. The typical plasticity index, I_p, of the subsoil is between 60-80% and the permeability of the soft subsoil, k is typically 10^{-7}cm/s.

Table 1. Comparative table of $O_{90,w}$, water flow and permeability between excavated and original geotextiles.

Location	Site A (Location X & Y)	Site B
Geotextile	nw-np-cf-pp* 280g/m²	nw-np-cf-pp* 200g/m²
Pore Opening Size $O_{90,w}$ (mm)		
Excavated - dirty[1]	0.120	0.140
Excavated - cleaned[1]	0.111	0.152
Original[2]	0.090	0.110
Water flow (normal to plane) (l/m²/s)		
Excavated - dirty[1]	49 - 54	79
Excavated - cleaned[1]	108 - 137	210
Original[2]	190	250
Permeability, k_n (cm/s)		
Excavated - dirty[1]	0.15 - 0.18	0.29
Excavated - cleaned[1]	0.35 - 0.52	0.79
Original[2]	0.5	0.5

* nonwoven needle-punched continuous filament polypropylene geotextile
[1] tested at Delft Hydraulics
[2] tested at Franzius Institute

5 ANALYSIS OF RESULTS

5.1 Hydraulic properties

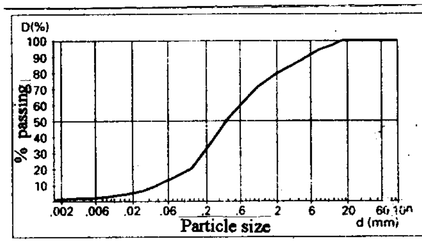
Comparison of dirty and cleaned geotextiles showed a difference in pore size of about 8%. In terms of consistency in the pore size opening measurements of nonwoven geotextiles, these differences are considered insignificant and it can be concluded that the pore size of the geotextile was not significantly influenced during the period the geotextiles were in service.

The excellent conditions of the revetment structures also indicated that the geotextiles performed well in retaining the subsoil. Thus, the design criteria for soil retention recommended by Wewerka (1986) for nonwoven needle-punched geotextiles in contact with cohesive soils with I_p>20%, the pore size $O_{90,w(original)}$<0.11mm was reasonable.

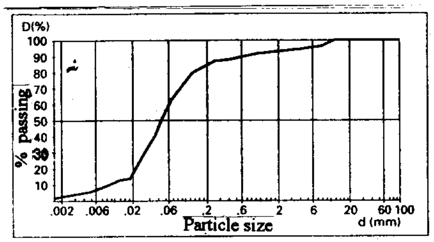
For the geotextile applied directly over the sand layer, the $O_{90,w}/d_{50}$ ratios for both dirty and cleaned

Table 2. Comparative table of mechanical and physical properties between excavated and original geotextiles.

Location	Site A (Location X & Y)	Site B
Strip tensile strength (N/5cm)		
Excavated	713	535
Original	780	560
% difference	-9%	-4%
CBR Puncture (N)		
Excavated	1805	1970
Original	3000	2150
% difference	-40%	-8%
Grab strength (N)		
Excavated	1118	778
Original	1080	760
% difference	+3%	+2%
Weight (g/m²)		
Excavated - dirty	2523	1242
Excavated - cleaned	313	228
Original	280	200
Thickness (mm)		
Excavated - dirty	5.25	3.90
Excavated - cleaned	2.60	2.25
Original	2.60	2.00



Site A - location Y
Clay and silt 14%
Sand 67%
Gravel 19%



Site B
Clay and silt 63%
Sand 31%
Gravel 6%

Figure 3. Particle size distributions of soils at site A and B.

geotextiles were less than 2 which complies to the soil retention design criteria for nonwoven needle-punched geotextiles in contact with non-cohesive soils, with C_u>6 and d_{85}/d_{50}>4 as proposed by the geotextile manufacturer (Loke, 1992).

The long term performance of geotextile permeability can be evaluated from the permeability ratio $k_{n(original)}/k_{n(dirty)}$ which was between 1.7-3.3. This range of reduction factor was significantly lower than the minimum allowable design reduction factor of $k_{n(original)}/k$>100 recommended by the manufacturer for nonwoven needle-punched geotextiles in contact with cohesive soils (Loke, 1992).

5.2 Mechanical properties

The results indicated that both the tensile strength and the puncture resistance of geotextiles were reduced. Significant reduction in puncture resistance of 40% (reduction factor about 1.66) was recorded in the geotextile from site A which clearly emphasized the importance of evaluating construction damage due to puncture when designing geotextile filters for coastal protection works.

6 RECOMMENDATION OF GEOTEXTILE FILTERS DESIGN CRITERIA

Two commonly applied design criteria that govern the selection of geotextile filters for coastal revetments are filtration criteria and resistance to construction damage.

Based on the above investigations, for nonwoven needle-punched geotextiles in contact with cohesive soils having Ip>20%, the pore size $O_{90,w}$<0.11mm provides adequate soil retention. If the geotextile is in contact with noncohesive soils with C_u>6 and d_{85}/d_{50}>4, the ratio $O_{90,w}/d_{50}$<2 can be applied.

The reduction in geotextile permeability with time necessitates that high initial permeability of geotextile is required. The ratio $k_{n(original)}/k$>100 is recommended for nonwoven needle-punched geotextiles in contact with cohesive soils to ensure adequate safety factor for long term performance.

The study confirmed that heavy weight nonwoven needle-punched continuous filament geotextiles provide high puncture resistance against construction damage. It also confirmed that high elongation property of the geotextile is necessary to conform to the uneven subsoil/rock armour profile to achieve a close contact between the subsoil and the rock armour. This helps to reduce direct dynamic wave impact, through the openings between rocks, on the geotextile and minimise geotextile puncture. It also helps to minimise migration of the subsoil beneath the geotextile which may result in revetment instability.

7 CONCLUSIONS

An investigation on the long term performance of nonwoven needle-punched geotextile filters placed over fine silty soils in coastal revetment works has been carried out. The results highlighted the applicability of the applied geotextile filter design critera and key geotextile properties critical for construction survivability in typical Asian coastal revetment projects.

Under the conditions described, the results showed that the nonwoven needle-punched continuous filament geotextiles performed well with insignificant change in the pore size. The permeability was found to have reduced but remained within the allowable design reduction factor to ensure continuous long term free water flow through the geotextiles.

The results also confirmed that both high puncture strength and tensile elongation of geotextiles are key design requirements to ensure high construction survivability of the geotextiles during and after construction.

8 ACKNOWLEDGEMENTS

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